30. (Unamended From Previous Version) An apparatus according to Claim 29, wherein said step of performing a binary search comprises iterated steps starting from a starting color value in device dependent color space, the iterated steps comprising:

dividing the device independent color space into multiple regions defined by device independent colors corresponding to small variations from the starting color in device dependent color space;

determining which of the multiple regions contains the device independent target color; and

updating the starting color value based on which region contains the device independent target color.

REMARKS

Claims 1 to 30 are in the application, of which Claims 7, 14, 21 and 28 have been amended. Claims 1, 8, 15, 22 and 29 are the independent claims herein. Reconsideration and further examination are respectfully requested.

The Office Action rejects Claims 7, 14, 21 and 28 under 35 U.S.C. § 112, second paragraph as being indefinite. Applicant amends Claims 7, 14, 21 and 28 as suggested in the Office Action. Accordingly, Applicant respectfully requests withdrawal of the rejection.

Claims 1, 3, 5 to 8, 10, 12 to 15, 17, 19 to 22, 24 and 26 to 30 are rejected under 35 U.S.C. § 102(e) over U.S. Patent No. 5,721,572 (Wan '572). Claims 2, 9, 16 and 23 are rejected under 35 U.S.C. § 103(a) over Wan '572 and U.S. Patent No. 5,553,199

(Spaulding). Claims 4, 11, 18 and 25 are rejected under 35 U.S.C. § 103(a) over Wan 572 in view of U.S. Patent No. 5,625,378 (Wan '378).

The present invention concerns deriving a reverse model look-up table based on a forward model look-up table whereby an entry in the reverse model look-up table is determined for a device independent target color based on a forward model look-up table whose entries represent device independent colors as a function of device dependent colors.

In conventional computer systems that print color images on a color printer, the precise colors actually printed by the printer are calculated by the computer using a look-up table. Specifically, the look-up table is arranged as a three-dimensional grid of cells, with each entry in the grid representing printer colorant values (such as cyan, magenta, yellow and black colorant values) as a function of some desired color in a different (usually device independent) color space. Based on a desired color, the computer accesses the look-up table to determine the printer colorant values.

To accomplish color matching across devices, it has become customary to employ a two-step procedure, which is illustrated with reference to exemplary device dependent and device independent color spaces. In the first step, an image, which is stored in a device dependent color space such as RGB color space, is transformed into a device independent color space such as CIEXYZ or CIELAB color space. This first transformation allows for compensation and calibration of device dependent characteristics, such as phosphor spectral characteristics of a monitor or spectral sensitivity characteristics of a scanner. In the second step, the device independent colors are

transformed into device dependent colors, such as CMY or CMYK colors. This second transformation allows for compensation of the output device's (e.g., a color printer's) characteristics.

One difficulty with this approach is the determination of entries for the look-up table that gives the transformation from device independent colors to device dependent colors for the printer. In the past, this look-up table was derived once at the factory, based on empirical measurements of a wide variety of color patches printed at fixed colors in the device dependent color space. A single derivation of a look-up table, however, does not allow for post-factory compensation based on effects such as printer aging, selection of different inks with different spectral characteristics, selection of different print media, and other effects which change printout characteristics. Although it is possible to recalibrate the printer by printout of new color patches and by empirical measurement of the resulting device independent colors, it is still difficult, tedious and time consuming to derive a new printer look-up table, even though such derivation is ordinarily performed by a computer.

To address the above problems, the present invention provides a fast iterative method for deriving a reverse model look-up table, with entries in the look-up table corresponding to device dependent colors as a function of device independent colors. The look-up table is derived from empirical measurements in device independent coordinates of predetermined device dependent color patches. The empirical measurements are preferably stored in a look-up table, with the look-up table commonly being referred to in the art as the "forward model". Accordingly, the look-up table that is

derived by the present invention from the forward model look-up table is referred to as the "reverse model" look-up table.

Referring to Claim 1, a method is recited for deriving a reverse model look-up table whose entries represent device dependent colors as a function of device independent colors, based on a forward model look-up table whose entries represent device independent colors obtained in response to printout of corresponding device dependent color components, wherein the forward model and the reverse model look-up tables both comprise a grid of cells in their respective color spaces with entries at each grid point of the grid, the method comprising the following steps to determine an entry in the reverse model look-up table for a device independent target color: performing a binary search of the forward model look-up table to locate a cell that contains the device independent target color, interpolating entries from the forward model look-up table at grid points that define the cell so as to obtain device dependent colors corresponding to the device independent target color, and storing the device dependent color at the grid point of the reverse model look-up table for the device independent target color.

Because the invention performs a binary search only for the purpose of locating the cell that contains the device independent target color, the binary search is quick and can be performed with relative ease. For example, in a situation where the forward model look-up table is a 9x9x9 uniform grid in CMY device dependent colors, the binary search can locate the cell for a device independent target color within about three and at most four iterations of the binary search. Moreover, since interpolation is performed

using the grid points for the cell so located, high color fidelity for the reverse model look-up table is obtained with good continuity and color gradient smoothness.

Wan '572 is not seen to describe generating a reverse model LUT in any sense, and certainly not in the manner set forth in Claim 1. In fact, Wan '572 expressly and specifically states that it does not describe a process by which an inverse LUT can be generated. As stated in Wan '572 (beginning at col. 4, line 17):

> "[a] detailed description of how to efficiently create the ILUT 40 is provided in the related application previously mentioned and entitled Method And Apparatus For Mapping Between Color Spaces and Creating A Three Dimensional Inverse Look-Up Table...."

The application cited by Wan '572 in the above text is an abandoned patent application (see col. 1, lines 12 to 16). Thus Wan '572 relies on an abandoned application for a description of the manner in which gamut descriptors are actually used to generate an ILUT, and Wan '572 expressly states that it does not describe generating an ILUT.

In actuality, Wan '572 is merely seen to describe the generation of gamut descriptors, which Wan '572 states are not the same as an ILUT. As stated in Wan '572, at col. 3, lines 44 to 61, a gamut descriptor is not an ILUT, and as compared to an ILUT, a gamut descriptor consists of a smaller set of points. Thus, Wan '572 expressly states that it does not describe generating an ILUT, and expressly states that what it does generate, i.e., gamut descriptors, are different from an ILUT. Therefore, Wan '572 is not seen to teach or suggest the method of deriving a reverse model LUT based on a forward model LUT as claimed in the present Application.

As further indication that Wan '572 fails to teach or suggest deriving a reverse model LUT, Applicant offers the following discussion of Wan '572 by first describing its manner of generating gamut descriptors, and then discussing the cited portions of Wan '572. It should be kept in mind, however, that according to Wan '572 the product that is generated is not an ILUT, but rather a set of gamut descriptors, which Wan '572 expressly states are not the same as an ILUT.

Generally, Wan '572 describes a process for generating a gamut descriptor whereby a table is first generated with entries corresponding to triangles on the boundary of the CMY space and corresponding triangles in Lab space. Once Wan '572 determines the gamut boundary in Lab space, Wan '572 then creates a gamut descriptor table by determining the gamut boundary for each of "k" layers in the Lab space and calculating a triangle, which corresponds to a layer in Lab space, using an Lab gamut boundary point and a set of coefficients that are applied to a Lab triangle from the gamut boundary triangle table. A corresponding CMY triangle is generated using the same coefficients and a triangle from the gamut boundary triangle table. An illustration of this process is provided in Wan '572 commencing at col. 8, line 42.

The cited portions of Wan '572 provide further details of generating the gamut descriptors. More particularly the portion of Wan '572 at col. 3, lines 39 to 62 states that a gamut descriptor is not an ILUT, as discussed above. Wan '572 states that a gamut descriptor can be used for mapping from device independent color space (DICS) to device dependent color space (DDCS), when an ILUT is not available. However, the cited portion of Wan '572 is not seen to provide any details as to how the mapping is to be done. Rather,

Wan '572 is seen to describe an alternative to an ILUT, which further evidences that gamut descriptors are different from an ILUT.

At col. 3, line 63 to col. 4, line 28, Wan '572 merely indicates that use of an ILUT for converting from DICS to DDCS is preferred over using backward interpolation and an LUT. The cited portion is not seen to disclose or suggest a method of deriving a reverse model LUT as in Claim 1.

At col. 7, lines 24 to col. 8, line 37, Wan '572 initially describes a technique for determining whether a point in Lab space is within the Lab gamut boundary. Then, Wan '572 describes the technique, which was discussed above, for calculating a table of gamut descriptors.

At col. 9, lines 9 to 16, Wan '572 describes an alternative to searching the table of triangles to locate a triangle that encloses the unit vector in the Lab space. The alternative uses a triangle range table that identifies the Lab layer range and angle range associated with each entry in the triangle table. As stated beginning at col. 9, line 31, a unit vector has an associated L-axis value which is compared with the range information. Similarly, an angle that is associated with the unit vector is also used to locate a triangle with an appropriate angle range.

At col. 5, lines 43 to 67, Wan '572 describes using triangular interpolation to determine a point that is inside a convex hull of a convex polyhedral cone. As a result of the interpolation, a set of three coefficients are calculated such that certain constraints, which are enumerated in equation (6), which immediately follows line 56 of col. 5, are satisfied. The coefficients are then used to generate a vector, x, in the CMY color space

that corresponds to a vector, y, in Lab space, both vectors being within the convex polyhedral cone defined in their respective color spaces.

At col. 8, lines 38 to 60, Wan '572 reiterates the process, which was discussed in the prior paragraph, to generate a vector, u_j, using a triangle and a set of coefficients. As discussed above, the remaining passages of the cited portion merely illustrate the process of generating a gamut descriptor table.

As indicated above, the result of the process described in Wan '572 is a set of gamut descriptors, which Wan '572 states is not the same as an ILUT. While Wan '572 indicates that the gamut descriptors may be used to generate an ILUT, Wan '572 does not provide any specifics as to how an ILUT can be generated. Accordingly, generation of gamut descriptors as described in Wan '572 is not seen to teach or disclose generating a reverse model look-up table using a forward model look-up table in any respect, and certainly not with respect to that described in Claim 1.

The remaining cited art is not seen to remedy the deficiencies of Wan '572. More particularly, Wan '378 is seen to describe the convex interpolation that is used in Wan '572 to generate a gamut descriptor. Wan '378 identifies points that enclose a given point in a first color space, determines coefficients that meet a specific set of conditions, and then applies the coefficients to a set of points in a target color space that correspond to the first color space's enclosing points in order to determine a point in the second color space that corresponds to the given point in the first color space.

Spaulding is also not seen to remedy the deficiencies of Wan '572. Rather, Spaulding is seen to describe creating black strategies for different levels of black and

corresponding gamut volumes for the CMY colorant values. This process is described, with reference to Fig. 10, commencing at col. 6, line 43.

Thus, none of the cited references are seen to disclose or suggest deriving a reverse model look-up table whose entries represent device dependent colors as a function of device independent colors, based on a forward model look-up table whose entries represent device independent colors obtained in response to printout of corresponding device dependent color components, wherein the forward model and the reverse model look-up tables both comprise a grid of cells in their respective color spaces with entries at each grid point of the grid, the method comprising the following steps to determine an entry in the reverse model look-up table for a device independent target color: performing a binary search of the forward model look-up table to locate a cell that contains the device independent target color, interpolating entries from the forward model look-up table at grid points that define the cell so as to obtain device dependent colors corresponding to the device independent target color, and storing the device dependent color at the grid point of the reverse model look-up table for the device independent target color.

Therefore, for at least the foregoing reasons, Claim 1 is believed to be in condition for allowance. Further, Applicants submit that Claims 8, 15, 22 and 29 are believed to be in condition for allowance for at least the same reasons.

The remaining claims are each dependent from the independent claims discussed above and are therefore believed patentable for the same reasons. Because each dependent claim is also deemed to define an additional aspect of the invention, however, the individual consideration of each on its own merits is respectfully requested.

In view of the foregoing, the entire application is believed to be in condition for allowance, and such action is respectfully requested at the Examiner's earliest convenience.

Applicant's undersigned attorney may be reached in our Costa Mesa, California office at (714) 540-8700. All correspondence should continue to be directed to our below-listed address.

Respectfully submitted,

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APPENDIX

VERSION WITH MARKINGS TO SHOW CHANGES MADE TO CLAIMS

7. (Amended) A method according to Claim 6 [1], wherein the predefined colors are in CMY or CMYK space, and the colors are measured in CIEXYZ or CIELAB space.

14. (Amended) An apparatus according to Claim 13 [8], wherein the predefined colors are in CMY or CMYK space, and the colors are measured in CIEXYZ or CIELAB space.

21. (Amended) Computer-executable process steps according to Claim 20 [15], wherein the predefined colors are in CMY or CMYK space, and the colors are measured in CIEXYZ or CIELAB space.

28. (Amended) A computer-readable medium according to Claim 27 [22], wherein the predefined colors are in CMY or CMYK space, and the colors are measured in CIEXYZ or CIELAB space.

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